SUPPLEMENTAL FEEDING OF LACTATING DOES INCREASED BODY CONDITION AND CIRCULATING LEPTIN BUT FAILS TO IMPROVE REPRODUCTIVE EFFICIENCY

A Senior Honors Thesis

by

KIMBERLY CAROL CANDLER

Submitted to the Office of Honors Programs
& Academic Scholarships
Texas A&M University
in partial fulfillment of the requirements of the

UNIVERSITY UNDERGRADUATE
RESEARCH FELLOWS

April 2001

Group: Biomedical Sciences

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April 2001

Group: Biomedical Sciences

ABSTRACT

Supplemental Feeding of Lactating Fallow Does

Increased Body Condition and Circulating Leptin but

Fails to Improve Reproductive Efficiency. (April 2001)

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Thirty six gestating Fallow does (*Dama dama*; BW=51.3kg) were allotted into groups: 1) Control (C; No Supplement; n=12), 2) Supplement (S; 4:1, corn:soybean meal; n=12), or 3) Rice Bran (R; 3:1:1, corn:soybean meal:20% fat rice bran; n=12) formulated to be isonitrogenous and isoenergetic and grazed coastal bermudagrass/ryegrass pastures. Groups S and R were fed .5kg ration/head/day for 112d. All does were weighed, body condition scored (BCS), and blood sampled at 7d intervals for 14d prior to and for 35d after weaning. Serum progesterone (P4) and leptin concentrations were determined using radioimmunoassay (RIA). Pregnancy was determined by ultrasonography 30 and 75 d after buck exposure. S does tended ($P<.075$) to lose less body weight (BW; -.062±.004kg/d) than C (-.073±.004kg/d) or R (-.071±.004kg/d). C does tended ($P<.08$) to have lower BCS than R but were lower ($P<.002$) than S. S does lost less ($P<.001$) BCS (-.636±.310) than C (-2.167±.297) with R being intermediate (-1.432±.310). Fawn birth weights did not differ (5.2±.2kg/d, 5.1$\pm$.2kg/d, 5.3 $\pm$.2kg/d; C, S, and R respectively). C fawns had the lowest ($P<.003$) average daily gain (ADG; .128$\pm$.010kg), S the highest (.185$\pm$.010kg) and R intermediate (162$\pm$.010kg). Circulating leptin (ng/ml serum) increased over time ($p<.006$) and differed by treatment ($p<.04$) with S being the highest and C and R being similar ($P<.10$) and lowest. Preweaning P4 was higher ($P<.003$) in S (2.4$\pm$.2ng/ml) than either C (1.5$\pm$.2ng/ml) or R does (1.7$\pm$.2ng/ml). 100% of S does were estrous cycling before weaning compared with 66% of C and 75% of R. Postweaning P4 increased over time ($P<.0001$) but was not affected by treatment ($P>.10$). By d 30 of the breeding season, 100% of S does were pregnant compared with 91% of C and R and all does were pregnant by d 75. Inclusion of rice bran failed to improve performance but corn and soybean meal supplement increased BCS and circulating leptin. Weaning and buck exposure resulted in equal breeding performance in thinner does.

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INTRODUCTION

Unlike many domestic livestock animals, research has been limited in the deer farming industry. Its growth in popularity since the 1970's has caused a rise in research to try to increase productivity and efficiency in the industry. Fallow deer (*Dama dama*) are currently farmed or ranched in over 35 countries in the world and are semi-domesticated and managed primarily for venison production. Methods for evaluating the reproductive potential and efficiency of fallow does are needed to maximize fawn crops and ensure optimal reproductive performance.

Non-native deer that are seasonal breeders such as fallow deer, generally fawn from May through July. Nutritional requirements for mature does are greatest after fawning because of milk production and the need to regain body condition. During this period in the southeastern U.S., available pastures consist of warm-season perennial grasses such as bermudagrass, bahiagrass, and dallasgrass. These warm-season grasses have lower nutritive value than legumes or cool-season grasses.

Deer are considered to be small ruminants. Unlike sheep and cattle, deer have smaller rumens and shorter digestive tracts per unit body weight. As a result, the same rations fed to cattle and sheep do not produce similar amounts of gain in deer. Feed passes through the deer's gut faster and is not digested as well as in ovine and bovine species. In general, deer require higher quality diets than do other ruminant animals such as cattle and sheep.

This thesis follows the style and format of the *Journal of Animal Science*.

Female fertility has been found to be positively related to body weight and fat reserves (Albon et al., 1983). It has also been noted in red deer that fertility may be associated with body composition, and that fat and heavy, but skeletally small, hinds have the greatest probability of being pregnant (Albon et al., 1986). Therefore, body condition and plane of nutrition prior to or during the rut may greatly influence female fertility and establishment of pregnancy. Body condition scoring prior to and throughout the breeding season may provide a means for assessing an animal's or herd's reproductive potential (Willard et al., 1994). The female's body condition is critical to the success or failure during fawning and the rut.

A nutrition-reproduction study evaluating the results of fat supplementation on postpartum reproductive performance in Brahman cows determined that rice bran with high concentrations of oleic and linoleic acids seemed to stimulate reproductive activity in the cows. By evaluating different dietary ingredients, studies showed that fat apparently enhances postpartum reproduction either by increasing the energy status of the animal or by other processes independent of energy intake (De Fries et al., 1998). Since rice bran has a unique composition of fatty acids which stimulate reproductive activity in Brahman cows, the results should be similar in deer species since both animals are ruminants. The purpose of this experiment is to determine the effects of nutritional supplementation and increased fat in the diet on fawn growth and subsequent reproductive performance of fallow females.

LITERATURE REVIEW

Importance of Deer Farming

Most individuals view deer as wild creatures hunted for food or sport. Game ranching is the management of deer for recreational hunting or venison production on large acreages of native rangeland. Unlike game ranching, there is a growing industry in today's economy for what is termed "deer farming." Deer farming refers to the raising of deer for venison, velvet antler, and oriental by-products (Haigh and Hudson, 1993). The number of deer farms began increasing worldwide in the mid-1970's due to the surge of activity in New Zealand and Europe in marketing venison and deer by-products. The climates in these areas allow cool-season grasses to grow and flourish; as a result, the deer are naturally provided with higher quality forages to help maintain a high level of animal performance. An increased demand for venison and deer by-products has been observed in the United States. The U.S. imported 626 tons of venison and by-products in 1991. In 1993, the estimated sale of deer and deer by-products produced in the U.S. was $3.8 million (Willard, 1996). The population of non-native deer in Texas has increased over 300% from 27,538 in 1974 to 90,112 in 1994 (Mungall and Sheffield, 1994). A 1996 survey of exotic hoof stock operations in Texas reported 106,000 non-native deer (Texas Agriculture Statistics Service, 1996). At the present time, even with this increase in deer population, U.S. venison production cannot meet the current demand; as a result, 80% to 90% of the venison marketed in the United States is imported from New Zealand (Evers, 1999a).

Deer farming can provide increased environmental health and numerous economic benefits. Since grasslands are used to meet most of the nutritional requirements of deer, it is an environmentally-friendly agricultural system that protects both soil and water. Non-native deer can reach slaughter weight on well managed pasture, therefore it is not necessary to grain feed in concentrated feeding operations such as practiced in poultry, swine, and beef operations. Venison is a lean meat that is low in fat and cholesterol, making it an attractive alternative to chicken and fish for today's health-conscious Americans.

While venison is the principle product from farmed deer, there are also markets for deer products such as "velvet antler," which refers to the entire growing antler that is harvested prior to calcification. Red deer stags and elk are raised to produce velvet antler, which can be sold for $75 to $125 per kg for use in Asiatic medicines and tonics. Velvet antler is removed from red deer bucks 55 to 70 days postantler casting. Deer hides, for use in suede leather products, and red deer tails, which possess a scent gland used in Asian herbal medicines and tonics, are just some of the by-products that can currently be marketed in today's economy (Golz, 1993).

Preferred Species

Unlike domestic livestock, research in the deer farming industry has been limited. Its growth in popularity since the 1970's has intensified research to increase productivity and efficiency in the industry. Fallow deer (*Dama dama*) are currently farmed or ranched in over 35 countries in the world and are semi-domesticated and managed primarily for venison production. This specie is known to produce a finer table venison than other species. Methods for evaluating the reproductive potential and efficiency of fallow does are needed to maximize fawn crops and ensure optimal reproductive performance. Research suggests a link between doe lactational status and body weight at weaning that may subsequently affect a doe's breeding potential (Willard et al., 1999).

Red deer (*Cervus elephus*) have been domesticated in many countries because they are relatively easy to handle. They are widely utilized for venison and velvet antler production. In red deer, female fertility has been found to be positively related to body weight and fat reserves (Albon et al., 1983). It has also been noted in red deer that fertility may be associated with body composition, and that fat and heavy, but skeletally small, hinds have the greatest probability of being pregnant at a given reproductive status (Albon et al., 1986). Therefore, body condition and plane of nutrition prior to or during the rut may greatly influence female fertility and establishment of pregnancy. Body condition scoring prior to and throughout the breeding season may provide a means for assessing an animal's or herd's reproductive potential (Willard et al., 1994).

Studies show that Rocky Mountain elk (*Cervus elephus nelsoni*), which are a close relative to the red deer, often experience nutritional stress from 60-days pre-calving through weaning. The female's body condition is critical to the success or failure during calving and the rut (Jackson, 2000). In addition to influences on birth weight and calf survival, inadequate feed intake during late pregnancy is associated with weak labor, increased dystocia, reduced milk production, delayed return to estrus, and lower breeding performance in elk females. Information obtained on female elk performance can also be applied to red deer due to their close genetic similarities.

Digestive Physiology

Deer are considered to be small ruminants. Compared to sheep and cattle, deer have smaller rumens and shorter digestive tracts per unit body weight (Brown, 1999). As a result, the same rations fed to cattle and sheep do not produce similar amounts of gain in deer. Feed passes through the deer's gastrointestinal tract faster and is not digested as well as in ovine and bovine species. In general, deer need higher quality diets than do other domestic animals. Similar to other animal species, deer nutritional requirements vary depending on (1) the sex of the animal, (2) age of the animal, (3) stage of growth, (4) the season of the year, (5) environmental factors such as extreme heat or cold, and (6) their physiological state, such as pregnancy, lactation, or antler growth (Brown, 1999).

Very little is known about the specific nutritional requirements of deer. Wild ruminants can be classified into three types depending on their feeding habits: grazers (consuming grasses and sedges), browsers (concentrate selectors consuming primarily forbs and shrubs), and intermediates or opportunistic feeders which can use either grasses, sedges, forbs, or shrubs (Hofmann, 1985). Cattle and sheep are considered grazers because they have a large rumen, allowing for slower fermentation rate and slower rate of passage through the rumen. As a result, they are able to utilize higher fiber diets of moderate digestibility. White-tailed deer, mule deer, moose, and roe deer are browsers, with relatively small rumens in proportion to their body size; therefore, they have a high rate of diet passage and fermentation which requires them to have many small feeding periods (8 to 12) throughout the day (Evers, 1999b). Due to this faster rate of passage, browsers require a higher quality diet low in fiber. They are not very useful as a domesticated specie to farm because they are not very adaptable. Elk, red deer, fallow deer, axis deer, and goats are a few examples of intermediate feeders. Their digestive system is between the grazers and the browsers, which allows them to utilize most plants with approximately six feeding periods per day (Evers, 1999b). The ability of these animals to use a higher fiber diet than deer classified as browsers, allows them to be farmed as domestic livestock on grass and legume pastures; however, none of the species are true grazers, like domestic cattle and sheep (Hofmann, 1985).

Nutrient Requirements

Unlike most domesticated farm animals of today, the specific nutritional requirements for farmed deer are still not well defined. Currently most of the nutritional data on cervids comes from the white-tailed deer. As a result, when formulating a ration for exotic hoofstock, a deer farmer must develop a ration between requirements for a white-tailed deer and domestic sheep or goats, and adjust for size (Brown, 1999). Nutrient requirements even vary between the two species preferred for deer farming. The nutrient requirement of a red deer is assumed to be twice that of a fallow since red deer weighs about twice as much as fallow deer (Golz, 1993).

Water is the most critical of all nutrients. Studies have shown that deer can survive about a month with little or no food, but animals will die in as little as three days without water. With even a moderate restriction in water, deer lose weight and go off feed (Lautier et al., 1988). Deer can obtain water from three sources: (1) free water, such as ponds, streams, and dew on plants, (2) preformed water, or that contained in plants, and (3) metabolic water produced in the animal's cells by metabolic means. Depending on the outside temperature, white-tailed deer are believed to need three to six liters of water per day (Brown, 1985). Like domestic farm animals, farmed deer should be provided with ample fresh water.

Proteins make up the building blocks for animal tissues. Proteins are needed for growth, reproduction, lactation, and normal maintenance of blood, hair, and body cell replacement. Proteins are also needed for velvet antler growth since it is made of the protein collagen before it mineralizes. Required protein for a weaned fawn is believed to be around 18-20%, possibly even higher (Ulrey et al., 1967). The recommended protein content for adult farmed red deer and others is 16 % (Haigh and Hudson, 1993). Mature deer in the wild can get by with minimal protein, 4% for maintenance and 10% for growth (Aseleson et al., 1996).

Pregnancy increases protein requirements, but lactation places the greatest demand on deer for protein. The milk of red deer contains between 6.3-8.8% protein depending on time of lactation (Landete-Castillejos et al., 2000). The does lacking in protein during lactation will probably not produce poorer quality milk, but simply less milk. In addition, does with twins would obviously have an even higher protein requirement, but twinning is unlikely to be a major factor because twinning in fallow and red deer is a rare occurrence (Armstrong et al., 1969; Chapman and Chapman, 1975).

Fiber is the primary source of carbohydrates. Since the deer is a ruminant, like cattle and sheep, it can digest fiber, known as cellulose. Fiber is useful to deer not only for energy, but also for keeping the rumen healthy. Deer need fiber and could not exist on a concentrate ration alone. This is extremely important when feeding or supplementing deer in captivity. Supplemental feeds should be pelleted, mixed-grain, high fiber rations. A 13-15% fiber ration is recommended as a minimum (Brown, 1999).

Lipids provide an important source of energy through fats and oils in the diet. There are no specific requirements for lipids; however, lipids have 2.5 times the amount of energy per gram than proteins and carbohydrates (Brown, 1999). As a result, oils found in various nuts, such as acorns, consumed by deer provide a high level of energy. Red deer milk contains 8.3-14.4% fat, depending upon lactation status (Landete-Castillejos et al., 2000). Deer gain fat during the summer and fall to prepare for winter, but they do not need actual fat in the diet to increase body condition. Deer are able to convert the energy found in carbohydrates into saturated adipose tissue. This allows deer to draw on fat reserves during nutrient restriction and convert the adipose tissue into energy when needed. A major concern of the deer farmer is the seasonal feeding changes of the deer and resultant body composition changes. Carcasses can be too fat at certain times of the year and too lean at other times.

Mineral requirements of deer are not elucidated at this time due to the difficulty of working these wild animals, and the lack of adequate facilities and large numbers of deer required for this particular type of work. The major minerals of concern are calcium (Ca) and phosphorus (P), which are needed for bone and antler growth, milk production, blood clotting, muscle contraction, and general metabolism.

Hardened deer antler is composed of approximately 22% Ca and 11% P (Brown, 1999). Many early studies found conflicting results. French et al. (1956) found that .09% Ca and .27% P were the minimal amounts required for antler growth. Another study determined that .64% Ca and .56% P were needed in the diet for proper antler development (McEwen et al., 1957). More recently, Grasman and Hellgren (1993) found that P requirements varied between .12% and .16% seasonally. One possible reason for such variation is the fact that bucks can store minerals in their skeleton and transfer them to the antler when needed. Bucks actually undergo osteoporosis and remove minerals from their bones during mineralization of the antlers. After mineralization, the lost minerals are returned to the bones through dietary intake.

Even less information is known about the possible requirements for macro- and micro-minerals. Deer will often use salt licks, which may indicate a need for sodium or it might just be palatable. Feeding trace-mineralized salt in the ration or providing free-choice salt and mineral blocks should adequately cover the deer's mineral requirements.

Vitamin requirements in deer are also not defined at this point. Vitamins are classified as either fat soluble (A,D, K and E) or water soluble (C and B complex). Fat soluble vitamins are stored in the body; whereas, water soluble vitamins are not stored and are needed by most animals on a daily basis. Since deer are ruminants, they contain microorganisms (bacteria and protozoa) in the rumen which produce all of the vitamin K and B complex the deer need. Also, ruminants do not require vitamin C. Vitamin A is converted from carotene in plants and is important for vision and reproduction. Youatt et al. (1976) reported deficiencies of vitamin A in wild deer. Unfortunately, vitamin A requirements in deer have not been defined. Minimal research has been done on vitamin D but it has been found that circulating concentrations of vitamin D in the blood varied with antler growth cycles in bucks (Van deer Eems et al., 1988). Vitamin D is needed for calcium absorption and metabolism in all animals, which supports Van deer Eems' findings. The requirements for vitamin D are still not known, but there have not been any symptoms of its deficiency reported in the literature.

Energy, itself, is not a nutrient. Instead it is a property of other nutrients such as proteins, lipids, and carbohydrates. Energy is probably the most variable of the requirements because it is dramatically affected by the environment. Energy can be used to power animal movement, but most of it is used as chemical energy to drive reactions necessary to convert feed into animal products and to maintain body temperature. Basal metabolism is the amount of energy needed to maintain body temperature, respiration, and a small amount of activity. Energy expenditures vary based on temperature and activity levels (Gates and Hudson, 1979). Additional energy requirements are needed for growth, reproduction, pregnancy, lactation, and antler growth. Deer need substantially more energy to maintain their body temperature in cold weather, especially if they are forced to move to seek food or avoid danger (Gates and Hudson, 1979). Ulrey et al. (1970) estimated maintenance energy required by a 54.4 kg (120 lb) white-tailed doe in winter to be about 3,192 Kcal/day of digestible energy. Standing increases the energy costs over lying down by about 9%. Locomotion increases energy costs depending on speed, surface, and vertical climb.

Effects of Nutrition on Reproduction

Non-native deer respond to management with increased rates of fawn production. Species such as the fallow, sika, and red deer are seasonal breeders and breed in the fall and early winter months. This is the time of year when forage production is most restrictive in Texas. Available pastures consist of warm season perennial grasses such as bermudagrass and bahiagrass that have a lower nutritional value than the legumes or cool-season grasses. To enhance reproductive traits, it is imperative that females be provided the proper nutrition during this critical reproductive time. A number of factors may contribute to doe fertility, including body weight and body condition before and during the breeding season, doe age, and a doe's previous reproductive history (Willard et al., 1999). Fawn productivity is also directly related to the nutritional levels consumed by the doe.

As in all mammals, most does lose weight and body condition (fat) during lactation. It is important for does to be in moderate body condition as they go into the breeding season to have high pregnancy rates. Does in extremely fat or thin condition fail to breed more often than does in moderate body condition. Willard et al. (1999) conducted a large experiment with fallow does in Texas and found that mature does weighing less than 36.3 kg (80 lb) had a pregnancy rate of 83.5%, does weighing over 43.5 kg (96 lb) had a pregnancy rate of 81.2% compared with a 94% pregnancy rate in does weighing between 36.3 and 40.8 kg (80 to 90 lb). Does losing too much weight and body fat during lactation should be supplemented in order to maintain their weights during the critical last months before weaning. This will result in heavier fawns at weaning as milk production will be stimulated, and it will result in does becoming estrous cycling earlier in the breeding season, leading to earlier breeding dates.

Fawn mortality is a major concern for deer farmers. Seasonal breeders that breed in the fall and early winter fawn in the summer months. Fawns born late in the season are exposed to high environmental temperatures and losses may occur due to heat and dehydration. As a result, by breeding does earlier in the season, earlier fawning could reduce losses to the herd. Landete-Castillejos et al. (2000) found that red hind milk yield decreased as fawning date was delayed. The births were classified into two groups: early (day 1 to 20) and late (day 33 to 70). Milk production was 83.7% greater in hinds fawning early. This difference increased as lactation proceeded (48.2%, wk 2 vs. 127.1%, wk 34). The growth of fawns during the first year of life is strongly correlated with milk production of its mother, but is not correlated with hind size. The effect of fawning date on milk yield encourages advancing the breeding season in deer whenever possible (Landete-Castillejos et al., 2000).

Studies show no significant differences in pregnancy rates due to doe age. A study using fallow does reported pregnancy rate for does that conceived early in the breeding season (during the first 30 days) being 80% for mature does, 83.5% for 2-yr old does, and 88.3% for yearling does (Willard et al., 1999). These results were similar to previous reports for fallow deer in which 85% of does under natural farm mating conditions were reported to conceive at first estrus matings (Asher, 1987). Mature fallow and red deer may exhibit three or more estrous cycles during a breeding season, younger does (< 2 yr) have been observed to have fewer estrous cycles, have a shorter breeding season (Asher and Adams, 1985), and exhibit estrous activity later than mature does (Asher et al., 1990). Willard et al. (1999) showed that weaning rates in a current study ranged from 57.7% for yearling does to 96.1% in a group of mature does, with an overall weaning rate of 77.9%. These findings are similar to New Zealand studies of red and fallow deer with average weaning rates from 71.2 to 81.4% (Mulley et al., 1990; Asher and Langridge, 1992). The tremendous loss of fawns (42.5%) for yearling does is of concern. Further investigations are needed to determine whether alterations can be made in the management of yearling does before and after fawning to prevent the losses in this young, inexperienced doe population. If lactation proves to be the issue for fawn mortality in yearling does, supplemental feeding could alleviate some of the nutritional stress and possibly increase milk production resulting in healthier fawns.

Previous reproductive performance can be a valuable tool in determining which animals to cull from the herd. Data suggests that does not producing a fawn the previous year or does that are inconsistent in producing a fawn from year to year are generally heavier and conceive later in the breeding season than more prolific does (Willard et al., 1999). Heavier does were associated with lower pregnancy rates. In contrast, studies of fallow deer in British deer parks have reported no apparent correlation between body weight, fawning rate, and overall lower pregnancy rate (Langbein and Putman, 1992). Using body weight as a management or culling tool should be done with caution;

however, lactational status as an indicator of reproductive efficiency may be an acceptable criterion for identifying and removing unproductive fallow does from the breeding herd.

Nutrition - Reproduction Interaction

Nutrient restriction is known to negatively affect reproduction. Nutrition restriction in female mammals has been shown to increase the period of postpartum anestrous, initiate onset of anestrous, decrease litter size, increase embryonic mortality, and cause infertility. An increased understanding of nutrient requirements and subsequent improvement to animal diets can provide a way to improve reproduction in livestock species. The profitability of any livestock production system is influenced by reproductive rate.

The effects of nutrient restriction on reproduction are probably best seen in human patients with the eating disorder, anorexia nervosa. This syndrome presents with amenorrhea, weight loss, behavioral changes in which the menstrual cycle stops, and signs of hypothalamic dysfunction, which can be reversed with proper nutrition and weight gain (Warren, 1996). This syndrome is predominately one of starvation, and thus a perfect example of the effects of nutrient restriction on reproduction.

Anorexics exhibit deficiencies in the secretion of the anterior pituitary produced gonadotropins, luteinizing hormone (LH), and follicle stimulating hormone (FSH); however, LH appears to be the most affected. As the name implies, FSH regulates growth of follicles on the ovary in females. LH also regulates follicle growth; however, only in later stages of follicular development. Additionally, a preovulatory surge of LH, stimulated by the estrogen induction of gonadotropin releasing hormone (GnRH) secretion from the hypothalamus is required for ovulation to occur (Driancourt et al., 1993). Amenorrhea in anorexia nervosa is mediated by a mechanism centered in the central nervous system which alters the signals reaching the hypothalamus and thereby alters the normal episodic secretions of GnRH which appears to be necessary for normal maturation to puberty and ovarian cyclicity (Warren, 1996). In anorexic patients, patterns of LH secretion reverted to a prepubertal pattern of secretion (Boyar et al., 1974), and when challenged with GnRH, anorexics demonstrated a prepubertal pattern of response to the GnRH (Warren et al., 1975). This prepubertal pattern of LH secretion places anorexic patients in a period of anestrous, which will remain until dietary nutrition is increased. If GnRH is administered every two hours over a period of time, puberty and menstruation with ovulation can be induced; thus, suggesting that the amenorrhea in anorexic patients is mediated by GnRH (Warren, 1996). Furthermore, the fact that these responses can also be reversed with proper nutrition suggests that nutrient restriction has a negative effect on reproduction specifically by decreasing the secretion of GnRH by the hypothalamus, thus decreasing the secretion of LH and FSH from the anterior pituitary.

During nutrient restriction there are a variety of hormones and substrates that are altered in nutrient restricted animals compared to non-restricted animals. It has been hypothesized that changes in fatty acids and growth hormone (GH), which increase in periods of undernutrition, may be inhibitory to LH secretion, and that insulin-like growth factor-I (IGF-I), insulin (Schillo et al., 1992) and leptin (Bringer et al., 1997), which decrease in periods of undernutrition, may be stimulatory to LH release. The increased GH secretion in undernutrition, but decreased IGF-I secretion, signifies an uncoupling of the somatotrophic axis during nutrient restriction, just as GH stimulates the synthesis and secretion of IGF-I from the liver. Simpson et al. (1991) determined that decreased GH secretion caused accumulation of body fat in heifers, but would also have resulted in decreased concentrations of IGF-I.

Similar to the events initiating amenorrhea in anorexic women, nutritional restriction has been reported to cause cessation of estrous cycles in cattle (Imakawa et al., 1986; Johnson et al., 1987; Richards et al., 1989), and postpubertal gilts (Roozeboom et al., 1993), and has been reported to extend the period of postpartum anestrous in cattle (Randel, 1990). This reduction in ovarian activity is again related to the effects of nutrient restriction on GnRH secretion (Driancourt et al., 1993). Animals with decreasing body weight have been shown to have an increased incidence of embryonic mortality and decreased litter size, although the causes have not been determined (Dunn and Moss, 1992). It is possible that reduced LH release may also play a role in this aspect of nutritional restriction as LH is important in the development of the corpus luteum. The corpus luteum, in turn, secretes progesterone which is necessary to maintain pregnancy (Leymarie and Martal, 1993).

In terms of priority for nutrients, the reproductive organs have a lower priority for nutrients than other tissues and organs; therefore, in times of nutrient deficiency, growth and development of the reproductive organs will be retarded. Research has shown that restricting the feed intake (60-85% of ad libitum) of growing–finishing pigs delays the onset of puberty by about 10-14 days (den Hartog and van Kempen, 1980; King, 1989). The nutritional effect on the onset of puberty possibly is mediated through its effect on growth rate, body composition, and metabolic rate (Booth, 1990; Hughes and Pearce, 1989; Kirkwood and Aherne, 1985). Studies show that undernutrition in early gestation has to be very severe to reduce embryo survival because when the ovum is fertilized, the embryo is given a very high priority for nutrient supply (Speer, 1982). Following the path of fetal development, nutrient requirements increase with advancing pregnancy. In sows, fetal weight is doubled over the last month of pregnancy, with growth acceleration occurring especially in the last ten days prior to parturition (Aherne and Williams, 1992). Maternal fasting for three days during late gestation causes fetal growth retardation in the rat (Davenport et al., 1990). Further research in sheep concluded that long term maternal undernutrition results in altered fetal growth and suggests that the somatotrophic axis may be involved in the distribution and optimal use of substrates during fetal life (Bauer et al., 1995). Consequently, fetal growth is dependent upon adequate nutrient supply across the placenta, which, in turn, is largely dependent on maternal nutrition and metabolism (Owens, 1991).

Leptin is a protein expressed in adipocytes and is thought to play a role in regulating food intake and reproduction (Duggal et al., 2000). Leptin injection has been shown to increase circulating gonadotropin concentrations, thus promoting ovarian follicular development (Barash et al., 1996). Leptin receptor mRNA has been found in both the brain and the ovary (Cioffi et al., 1996), suggesting that leptin may act at either the level of the brain or the hypothalamus to alter reproduction. Keisler et al. (1999) determined that hypothalamic leptin receptor expression is greater in feed-restricted ewes than in well-fed ewes. There was a significant positive correlation between body condition score and plasma leptin concentrations. When concentrations of leptin were assessed over time, underfed ewes exhibited a dramatic reduction in plasma leptin values. Furthermore, these data provide strong evidence that, in sheep, the variations in plasma concentrations of leptin are related to body fatness and nutritional status (Delavaud et al., 2000). Leptin has also been significantly correlated with increased fat mass in women (Kohrt et al., 1996) and increases in weight have been shown to induce increased circulating leptin concentrations (Kolaczynski et al., 1996). Rising leptin concentrations have been associated with initiation of puberty in animals and humans. Normal leptin concentrations are needed for maintenance of menstrual cycles and normal reproductive function (Mantzoros, 2000). Likewise, leptin concentrations are decreased in subjects with anorexia nervosa, and this decrease is associated with weight loss and decreased percent body fat (Grinspoon et al., 1996). Therefore, similar to decreased IGF-I and insulin concentrations, decreased leptin concentrations may mediate the effects of nutrient restriction on reproduction.

Although grazing ruminants do not consume significant quantities of fat under natural conditions, the addition of fat to ruminant diets to promote positive energy balance has been a common practice (Byers and Schelling, 1998; Coppock and Wilks, 1991). In cattle, an increase in the consumption of dietary fat positively modified a number of ovarian physiological processes, including follicular growth and function

(Hightshoe et al., 1991; Wehrman et al., 1991; Ryan et al., 1992), the lifespan of induced corpora lutea (Williams, 1989; Ryan et al., 1995), and the duration of postpartum anovulatory intervals (Wehrman et al., 1991; Espinoza et al., 1995; Beam and Butler, 1997). The precise mechanisms through which increments in dietary fat modify ovarian physiology remain undetermined. Research conducted by Thomas et al. (1997) found that cows fed a polyunsaturated diet had an increase in the number of developing follicles at any given time during the estrous cycle in comparison to cows receiving a control diet, saturated fatty acid diet, or highly unsaturated fatty acid diet. Studies also suggest that the enhanced follicular development and luteal function observed in fat-supplemented cows are due to changes in serum concentrations of metabolites and metabolic hormones that may act at the hypothalamic-pituitary-ovarian axis to influence GnRH secretions. Further research has shown a tendency for rice bran-fed cows to have higher pregnancy rates than control-fed cows (De Fries et al., 1998). Oleic and linoleic fatty acids represent more than 70% of rice bran fatty acid composition, thus making it a common polyunsaturated supplement to utilize (Rukmini and Raghuram, 1991). Since rice bran has a unique composition of fatty acids which stimulate reproductive activity in cows, the results should be similar in deer species since both animals are ruminants.

Several metabolic hormones are altered by subsequent nutritional status and, when altered by nutrient restriction, are capable of altering reproduction. Nutritional restriction can increase the period of postpartum anestrous, initiate onset of anestrus, decrease litter size, increase embryonic mortality, and cause infertility. As a result, it can be a major factor in the profitability of any animal agriculture operation. Decreased

IGF-I, insulin, and leptin may all contribute to the effects of nutrient restriction on reproduction. These hormones elicit their effects by altering patterns of GnRH secretion at the level of the hypothalamus, which leads to altered LH pulsatility. The disruptions in reproduction lead to either short or long term infertility, depending on the length of nutrient restriction. By developing an understanding of the mechanisms affecting nutrition-reproduction interactions, preventative measures can be taken to alleviate some of the consequences of nutrient restriction.

MATERIALS AND METHODS

Animals and Management

Procedures took place at the Texas A&M University Agricultural Research and Extension Center in Overton, Texas. The investigation was conducted during the summer of 2000 through the winter of 2001. Three groups of twelve bred fallow does, each weighing about 51kg, were randomly stocked on three 0.405 hectare pastures. One group of fallow deer were fed a corn grain, rice bran, and soybean meal supplement (corn grain 60%: rice bran 21%: soybean meal 19%) at .5kg ration/head/day prior to and through the duration of lactation. One group of fallow deer were on a corn grain and soybean meal supplement (corn grain 80%: soybean meal 20%) at .5kg ration/head/day prior to and through the duration of lactation. One group of fallow deer were used as a control group and received no supplementation.

Coastal bermudagrass pastures which had been overseeded with ryegrass the previous autumn were mowed off in late May and fertilized according to soil tests. Access to coastal bermudagrass hay was added to all groups due to a lack in rainfall causing limited pasture growth. Animals were allowed ad libitum access to water, salt, and minerals. For data collection, does were herded from pastures to a working facility that was equipped with a drop-floor deer cradle and scale that restrained the does but minimized stress. The care and use of animals for this project was approved by the Institutional Animal Care and Use Committee and followed the appropriate guidelines for the care and use of agricultural animals in research and teaching.

Data Collection

Weight and body condition scores were recorded at the beginning of the experiment and sampled at 7 day intervals for 14 days prior to and for 35 days after weaning. Fawns were tagged for identification and weighed at birth and at the end of the study to determine average daily gain. Blood samples were drawn at 7 day intervals for 14 days prior to and for 35 days post-weaning to determine if supplemented females came into the breeding season earlier than the control group of females. Serum progesterone concentrations were determined using radioimmunoassay procedures for steroid analysis (Williams, 1989). The progesterone (≥/ng/ml serum) concentrations served as an indicator to conclude if the supplemented females began estrous cycling before the control females. Serum leptin concentrations were determined using radioimmunoassay procedures to determine circulating leptin concentrations in the blood (Delavaud, 2000). Does were ultrasounded transrectally for pregnancy at approximately day 30 and day 75 after exposure to bucks.

Statistical Analysis

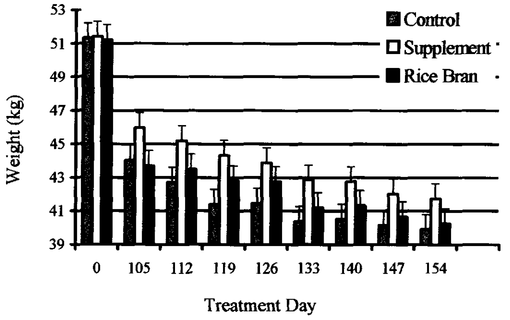
Birth weight, fawn average daily gain, doe average daily gain, doe change in body condition, postweaning mean progesterone concentrations, and area under the curve data were all analyzed using General Linear Model procedures of SAS (SAS Inst. Inc., Cary, NC). Serum progesterone and leptin concentrations and doe body weight and body condition score were analyzed using analysis of variance procedures of SAS specific for repeated measures. Mean separation was determined using the Pdiff option of SAS. Pregnancy data were analyzed by chi-square procedures of SAS.

RESULTS

Doe Status

Supplemented does tended (P < 0.075) to lose less weight (-.062 ± .004kg/d) than control does (-.073 ± .004kg/d) or rice bran fed does (-.071 ± .004kg/d; Figure 1). Research suggests that there may be a possible link between doe lactational status and body weight at weaning that may subsequently affect a doe's breeding potential (Willard et al., 1999). Control does tended (P < 0.08) to have lower body condition score than rice bran fed does which were lower (P < 0.002) than the supplemented does.

Figure 1. Body weight (LS means ± SE) of does supplemented with a 3:1 corn:soybean meal supplement at .5kg ration/head/day; a 3:1:1 corn:soybean meal:rice bran supplement at .5kg ration/head/day; or unsupplemented prior to and through the duration of lactation; Trt (P = 0.2); Time (P < 0.0001); Trt x Time (P = 0.2).



Supplemented does lost less (P < 0.001) body condition (-.636 ± .310) than control (-2.167 ± .297) with rice bran fed does being intermediate (-1.432 ± .310; Figure 2). Pre-weaning progesterone was higher (P < 0.003) in supplemented does (2.4 ± .2ng/ml) than either control (1.5 ± .2ng/ml) or rice bran fed does (1.7 ± .2ng/ml; Figure 3).

Figure 2. Body condition score (LS means ± SE) of does supplemented with a 3:1 corn:soybean meal supplement at .5kg ration/head/day; a 3:1:1 corn:soybean meal:rice bran supplement at .5kg ration/head/day; or unsupplemented prior to and through the duration of lactation; Trt (P < 0.0001); Time (P < 0.0001); Trt x Time (P = 0.2).

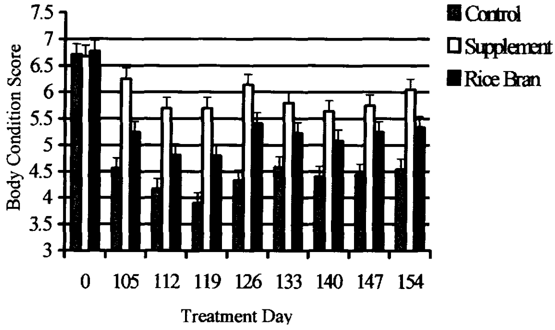
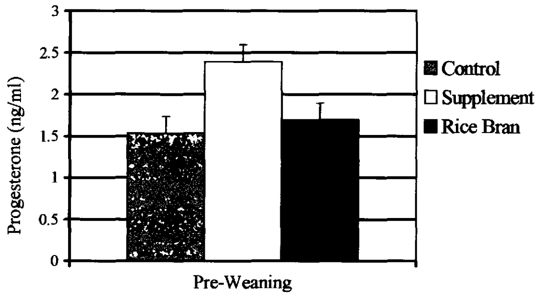


Figure 3. Pre-weaning serum progesterone concentrations (LS means ± SE) of does supplemented with a 3:1 corn:soybean meal supplement at .5kg ration/head/day; a 3:1:1 corn:soybean meal:rice bran supplement at .5kg ration/head/day; or unsupplemented prior to and through the duration of lactation; Trt ($P < 0.003$).



Circulating leptin (ng/ml serum) increased over time ($P < 0.006$) and differed by treatment ($P < 0.04$) with the supplemented does being the highest with the control and rice bran groups being similar ($P < 0.10$) and lowest (Figure 4). Of the supplemented doe group, 100% were estrous cycling before weaning compared with 66% of control and 75% of rice bran fed does (Table 1). Post-weaning P4 increased over time ($P < 0.0001$) but was not affected by treatment ($P > 0.10$; Figure 5). By day 30 of the breeding season, 100% of supplemented does were pregnant compared with 91% of control and rice bran fed does (Table 2). All does were pregnant by day 75.

Figure 4. Leptin concentrations (LS means ± SE) of does supplemented with a 3:1 corn:soybean meal supplement at .5kg ration/head/day; a 3:1:1 corn:soybean meal:rice bran supplement at .5kg ration/head/day; or unsupplemented prior to and through the duration of lactation; Trt ($P < 0.04$); Time ($P < 0.006$); Trt x Time ($P = .052$).

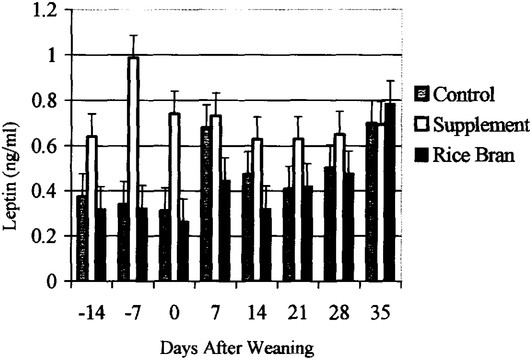


Table 1. Percent of does estrous cycling based on circulating progesterone concentrations (≥1ng/ml) in blood serum supplemented with a 3:1 corn:soybean meal supplement at .5kg ration/head/day; a 3:1:1 corn:soybean meal:rice bran supplement at .5kg ration/head/day; or unsupplemented prior to and through the duration of lactation; ($P = 0.12$).

Treatment		Estrous Cycle Present	Percentage (%)
Control	n = 12	n = 8	67
Rice Bran	n = 12	n = 9	75
Corn/Soybean	n = 12	n = 12	100

Figure 5. Post-weaning serum progesterone concentrations (LS means ± SE) of does supplemented with a 3:1 corn:soybean meal supplement at .5kg ration/head/day; a 3:1:1 corn:soybean meal:rice bran supplement at .5kg ration/head/day; or unsupplemented prior to and through the duration of lactation; Trt ($P = 0.5$); Time ($P < 0.0001$); Trt x Time ($P = 0.1$).

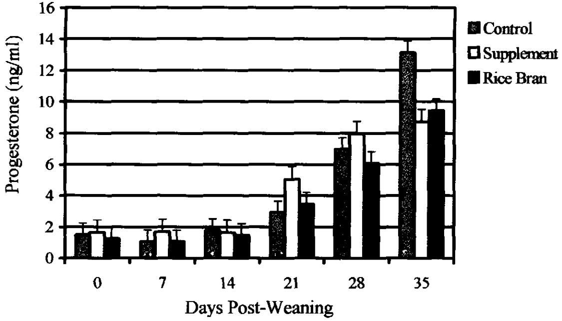


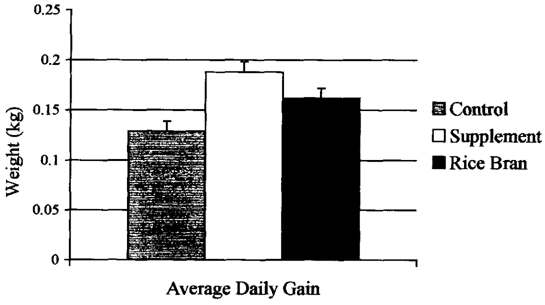
Table 2. Pregnancy rates in does on day 30 after buck removal supplemented with a 3:1 corn:soybean meal supplement at .5kg ration/head/day; a 3:1:1 corn:soybean meal:rice bran supplement at .5kg ration/head/day; or unsupplemented prior to and through the duration of lactation; ($P = 0.62$).

Treatment	Ultrasounded Pregnant	Percentage (%)
Control	n = 11	92
Supplement	n = 11	100
Rice Bran	n = 11	92

Fawn Status

Fawn birth weights did not differ (5.2 ± .2kg/d, 5.1 ± .2kg/d, 5.3 ± .2kg/d; C, S, and R respectively). Control fawns had the lowest ($P < 0.003$) average daily gain (.128 ± .010kg), supplemented fawns had the highest (.185 ± .010kg) and rice bran fawns were intermediate (.162 ± .010kg; Figure 6).

Figure 6. Average daily weight gain (LS means ± SE) of fawns supplemented with a 3:1 corn:soybean meal supplement at .5kg ration/head/day; a 3:1:1 corn:soybean meal:rice bran supplement at .5kg ration/head/day; or unsupplemented prior to and through the duration of lactation; Trt ($P < 0.003$).



DISCUSSION

Nutritional requirements for mature does are greatest after fawning due to milk production and the need to regain body condition. In the present study, supplementation with a 3:1 corn:soybean meal mixture at 1% of body weight per day resulted in less loss in body weight in lactating fallow does whereas supplementation with a 3:1:1 corn:soybean meal:rice bran mixture at 1% body weight per day was intermediate in loss in body weight.

Supplementing lactating does significantly improved body condition compared to does receiving no supplementation ($P < 0.001$). Does supplemented with 3:1:1 corn:soybean meal:rice bran mixture at 1% body weight had intermediate body condition score. Increasing the fat in the diet failed to improve doe body weight or body condition score as much as the lower fat but isoenergetic and isonitrogenous corn:soybean meal supplement. Willard et al. (1999) concluded that does in extremely fat or thin condition fail to breed more often than does in moderate body condition. As in all mammals, most does lose weight and body condition (fat) during lactation. It is important for does to be in moderate body condition as they go into the breeding season to have high pregnancy rates. Supplementing lactating does prevents weight loss. Does that are losing too much weight and body fat during lactation may require supplementation in order to maintain their body weight and milk production during the critical last months before weaning.

Fawns of does supplemented with a 3:1 corn:soybean meal mixture at 1% body weight had significantly higher average daily gain than fawns of non-supplemented does ($P < 0.003$). Fawns of does supplemented with a 3:1:1 corn:soybean meal:rice bran mixture at 1% body weight were intermediate in average daily gain. In red deer hinds, the growth of calves during the first year of life is strongly correlated with milk production of its mother, but is not correlated with hind size. The effect of calving date on milk yield encourages advancing the breeding season in deer whenever possible (Landete-Castillejos et al., 2000). High weaning weights and minimal fawn loss are essential in having a successful deer farming operation.

While supplementing lactating does with a 3:1 corn:soybean meal mixture at 1% body weight appears to increase pre-weaning progesterone concentration, which indicates earlier ovarian activity, over unsupplemented does and does supplemented with a 3:1:1 corn:soybean meal:rice bran mixture at 1% body weight ($P < 0.033$), pregnancy rates were not affected. Research conducted by De Fries et al. (1998) indicated that there was a tendency ($P = .09$) for rice bran-fed cows to have a higher pregnancy rate than control-fed cows. This occurred despite no differences in postpartum interval or serum progesterone concentrations during the first normal estrous cycle. As a result, the enhanced pregnancy rate can not be attributed to increased progesterone concentrations before breeding. The rice bran-fed cows did; however, gain more weight during the postpartum period which may be the cause of the increased pregnancy rate. Rice bran with high concentrations of oleic and linoleic acids seem to stimulate reproductive activity in cows; however, rice bran does not produce similar results in deer species despite both being ruminants.

Rice bran supplement in the diet did not increase reproductive performance. Failure of fat supplementation to influence postpartum interval has been previously observed and reported by some researchers (Carr et al., 1994; Lammoglia et al., 1996), whereas others have reported positive influences of fat supplementation on postpartum reproductive function (Wehrman et al., 1991). Studies show that fat apparently enhances reproduction either by increasing the energy status of the animal or by other processes independent of energy intake (De Fries et al., 1998). Unfortunately similar results are not seen in cervids. Since supplementing rice bran does not affect reproductive performance, further investigation is necessary to determine ways of enhancing the onset of the breeding season in cervids. Seasonal breeders that breed later in the fall and early winter, fawn in the late summer months. Fawns born late in the season are exposed to high environmental temperatures and losses may occur due to heat and dehydration. As a result, by breeding does earlier in the season, earlier fawning could reduce loss to the herd.

Inclusion of rice bran failed to improve performance but feeding a corn and soybean meal supplement increased body condition score and circulating leptin. Likewise, a study on goats conducted by Sahlu et al. (1992) determined that a low protein (8.8% crude protein (CP)) diet may be inadequate to meet a does' protein requirement during late gestation, but there was no apparent advantage in feeding a high protein (14.3% CP) ration rather than a medium protein (11.0% CP) ration. Feeding a high fat supplement does not show a significant improvement over a standard corn and soybean meal feed. As a result, feeding a standard ration can provide similar or improved responses in body condition score, body weight, and leptin concentrations when compared to a higher fat supplement. Thomas et al. (1997) determined that beef cows fed supplemental dietary fats exhibit remarkable changes in several metabolic and reproductive characteristics, including increased follicular growth and shortened anovulatory intervals postpartum. Dietary polyunsaturated fat seems to enhance follicular growth more than either saturated or highly polyunsaturated fat. Practical feeding schemes using fat to enhance reproductive performance in cattle may benefit when polyunsaturated plant oils, such as soybean oil which has linoleic acid as a major constituent, are chosen instead of saturated or polyunsaturated fats but may not be useful to cervids.

Does receiving the corn grain and soybean meal diet had higher leptin concentrations than the control and rice bran-fed groups. Leptin concentrations in these fallow does were associated with body weight and body condition score as reported in sheep (Delavaud et al., 2000). Studies show a significant positive correlation between body condition score and plasma leptin concentrations. When concentrations of leptin were assessed over time, underfed ewes exhibited a dramatic reduction in plasma leptin values. Furthermore, data provides strong evidence that, in sheep, the variations in plasma concentrations of leptin are related to body fatness and nutritional status (Delavaud et a., 2000). In red deer, female fertility has been found to be positively related to body weight and fat reserves (Albon et al., 1983). It has also been noted in red deer that fertility may be associated with body composition, and that fat and heavy, but skeletally small, hinds have the greatest probability of being pregnant at a given reproductive status (Albon et al. 1986). Therefore, body condition and plane of nutrition prior to or during the rut may greatly influence female fertility and establishment of pregnancy. Supplementation of rice bran did, however, increase body weight and body condition scores of the does, but not as greatly as the corn and soybean meal supplement.

SUMMARY

Fallow does fed a 3:1 corn:soybean meal at 1% body weight per day showed improved body weight, body condition score, and fawn average daily gain. Additional fat from the rice bran failed to improve body weight, body condition score, and fawn average daily gain as much as the standard 3:1 corn: soybean meal mixture. Reproductive performance was not improved by any supplemental treatment. As a result, inclusion of rice bran failed to improve doe performance, but supplement consisting of corn and soybean meal increased body condition and circulating leptin concentrations. Weaning and buck exposure resulted in equal breeding performance in thinner does.

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